

XID+ a new prior-based extraction tool for Herschel-SPIRE maps

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Abstract. We present XID+ a new generation of software for prior-based photometry extraction in the Herschel SPIRE maps. Based on a Bayesian framework, XID+ allows the inclusion of prior information and gives access to the full posterior probability distribution of fluxes. XID+ is developed within the Herschel Extragalactic Legacy Project (HELP) and is available at https://github.com/H-E-L-P/XID_plus.

1. The Context

ESA's *Herschel Space Laboratory* (Pilbratt et al. 2010) has given us an unprecedented view of the far-infrared sky. To take most advantage of its data, one must nevertheless beat the confusion due to the large beam size of its instruments, as illustrated in figure 1.

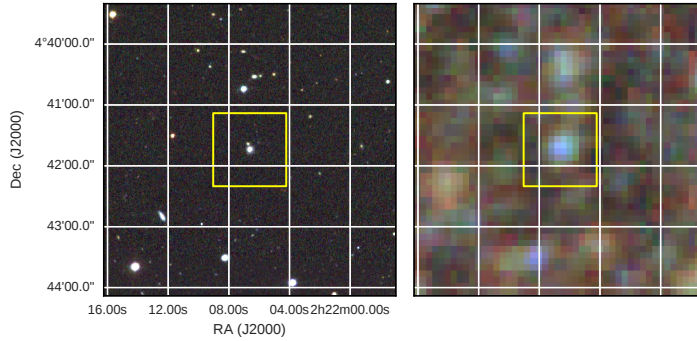


Figure 1. Same part of the sky observed in optical (composite image of SDSS g, r, and i bands) and with Herschel (composite image of the three SPIRE bands). The square in the centre delimits the zone used in the following figures. Because of the large beam, multiple sources cannot be distinguished in the SPIRE maps; we refer to this as confusion.

The *Herschel Extragalactic Legacy Project* (HELP) is a European Research Executive Agency funded project that aims to capitalise on the distant Universe surveys made by Herschel. To overcome the confusion problem, HELP has developed XID+ (Hurley et al. 2016), a new software to perform prior based source extraction on con-

fused images. XID+ is being used on maps from Herschel SPIRE and PACS instruments as well as on Spitzer MIPS maps.

2. Using Bayesian Methods Gives Access to Full Posterior Probability

One way to overcome the confusion is to use information from resolved observations, at other wavelengths, that give the positions of known sources. XID+ uses Bayesian inference methods implemented within the Stan framework (Carpenter et al. 2016) to use this information to compute fluxes. Compared to maximum likelihood methods, this gives access to the full posterior probability of the flux distribution as illustrated in figure 2.

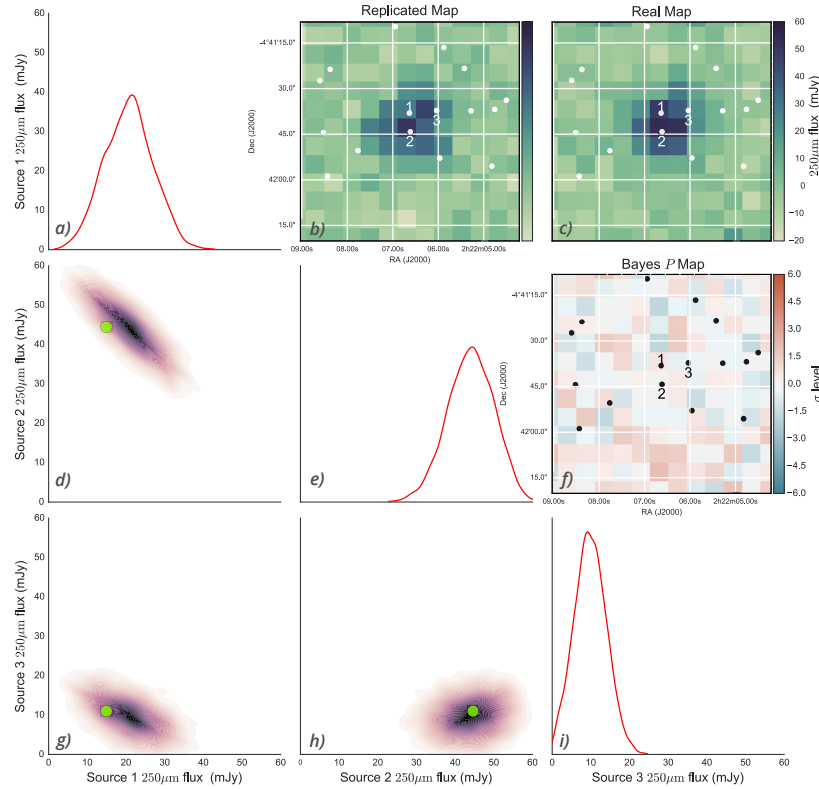


Figure 2. Analysis of the SPIRE $250\,\mu\text{m}$ fluxes of three nearby sources with XID+ using only the position as prior information.

- *c*) is the actual SPIRE map;
- *d*), *g*) and *h*) are the joint probability distributions of the fluxes for each source pair;
- *a*), *e*) and *i*) are the marginalised probability distributions of each source flux;
- *b*) is the replicated map corresponding to the green dots on the joint distributions.

3. p -Value Maps

One interesting output of XID+ is the p -value map. It indicates how well the real map is explained by the model and shows unexpected excesses or lacks in fluxes. Figure 3 shows a zone with an unexplained excess in the SPIRE 500 μm filter that may reveal some interesting objects not present in the original catalogues.

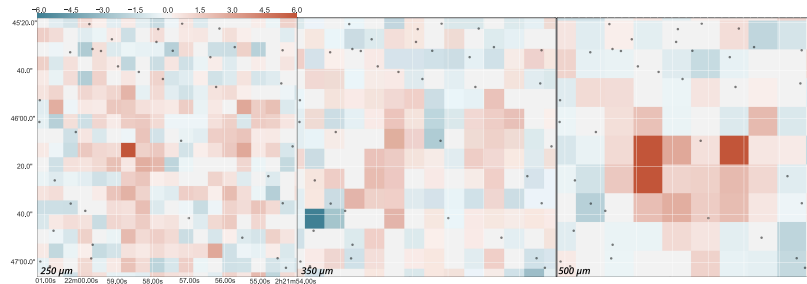


Figure 3. p -value maps of the same area for SPIRE 250, 350, and 500 μm .

4. Adding More Prior Information

The use of a Bayesian framework makes it possible to add new prior information. For instance, we can use our prior knowledge on redshifts, combined with some simple spectral energy distributions (SEDs) to better constrain the fluxes by eliminating impossible combinations. This is illustrated by figure 4: the red (lighter grey in black and white) probability density functions (PDFs) are those that don't use the redshift and SEDs as prior, the blue (darker grey) are those that use it.

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This research made use of Astropy, a community-developed core Python package for Astronomy (Astropy Collaboration 2013). This research made use of APLpy, an open-source plotting package for Python hosted at <http://aplpy.github.com>.

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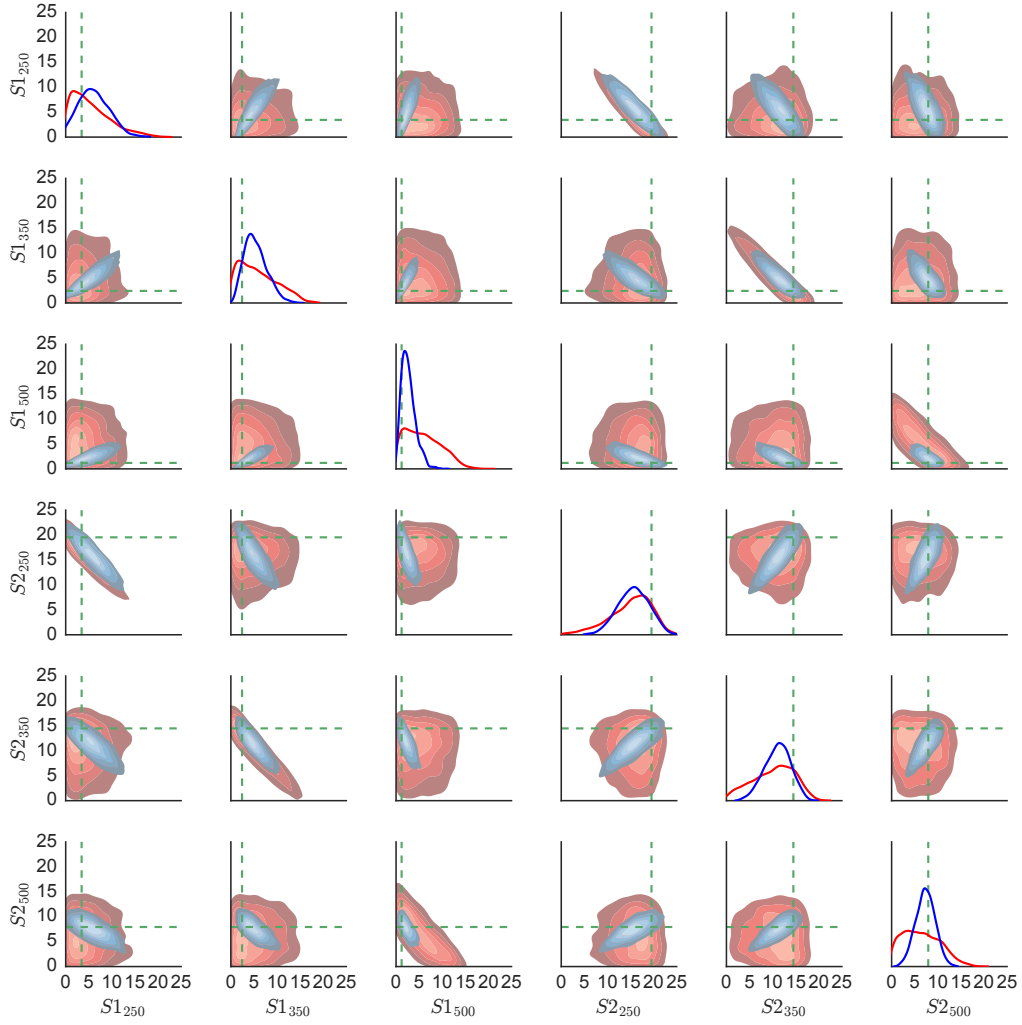


Figure 4. Effect of adding redshift value and simple SEDs as prior information.